Canada

ENFOR PROJECT P-362

THE COMPETITIVE POSITION OF FUELWOOD FROM PROPOSED ENERGY PLANTATIONS IN NEWFOUNDLAND

for

Canadian Forestry Service

Newfoundland Forest Research Centre

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FOREWORD

ENFOR is the acronym for the ENergy from the FORest (ENergie de la FORêt) program of the Canadian Forestry Service. This program of research and development is aimed at securing the knowledge and technical competence to facilitate in the medium to long term a greatly increased contribution from forest biomass to our nation's primary energy production. It is part of the federal government's efforts to promote the development and use of renewable energy as a means of reducing dependence on petroleum and other non-renewable energy sources.

The ENFOR program is concerned with the assessment and production of forest biomass with potential for energy conversion and deals with such forest-oriented subjects as inventory, harvesting technology, silviculture and environmental impacts. (Biomass Conversion, dealing with the technology of converting biomass to energy or fuels, is the responsibility of the Renewable Energy Division of the Department of Energy Mines and Resources). Most ENFOR projects, although developed by CFS scientists in the light of program objectives, are carried out under contract by forestry consultants and research specialists. Contractors are selected in accordance with science procurement tendering procedures of the Department of Supply and Services. For further information on the ENFOR Biomass Production program, contact ...

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SUMMARY

1. The objective of this report is to assess the competitive position of biomass from proposed energy plantations in Newfoundland.

2. The assessment is based on a "usable energy" approach taking into account the heat value and cost of each feedstock as well as the operating parameters, cost configurations and efficiency of the system recovering energy from the feedstock.

3. Recovering the energy value from fuelwood normally involves either direct combustion or conversion to gaseous or solid fuels followed by combustion. There is considerable experience and continuing interest in Newfoundland in the use of wood as an energy feedstock, particularly in the generation of steam for process and space heating requirements. The analysis in this report is based on the direct combustion of fuelwood to produce steam.

4. The following three energy feedstocks are examined in this report: biomass from hypothetical energy plantations in central Newfoundland, biomass from non-commercial natural forests adjacent to the hypothetical plantations and fuel oil.

5. Cost estimates for the hypothetical energy plantations were developed through the use of a NRCC model designed to estimate the cost of energy plantation biomass in eastern Ontario. The cost estimate developed in this report for biomass from energy plantations in Newfoundland is $54 per ODT. In comparison, the cost estimate developed by the NRCC for biomass from energy plantations based on a similar management regime in eastern Ontario was $31.76 per ODT ($1985). Both estimates are based on the use of specialized equipment requiring further development.

6. Estimates of the cost of steam generated from each feedstock are as follows:

   - biomass from energy plantations $6.63 per GJ
   - biomass from non-commercial forests $6.60 per GJ
   - fuel oil (#6) $7.68 per GJ

   The cost of steam generated from energy plantation biomass is very similar to the cost of steam generated by biomass from non-commercial forests and significantly lower than steam produced from fuel oil. Consequently, the findings suggest that on the basis of current price and cost levels and the specific assumptions used in the analysis, energy plantation biomass could compete with the two major feedstocks used for the generation of steam in central Newfoundland.

7. The cost of biomass from the hypothetical energy plantations could increase from $54/ODT to $70/ODT and still remain competitive with fuel oil at cost and price levels prevailing in mid 1987.

8. Many positive social and economic benefits could accrue from the development of energy plantations in Newfoundland. Implementation of the plantations would assist in reducing Newfoundland's dependence upon imported oil, provide sustainable rural employment opportunities, increase expenditures on local goods and services, increase government revenues, effectively utilize marginal forest land and stimulate forestry research.

9. Energy plantations utilize a developing technology. At present there are no large scale commercial plantations in the boreal forest regions dedicated to the production of energy feedstocks. Major risks and uncertainties are still present and only experience gained from large scale commercial operations over a period of time will fully identify their impact.

10. Future implementation of energy plantations in Newfoundland will be largely dependent upon the relative prices and availability of alternative fuels, the commercial availability of specialized plantation machinery, the reduction of biological and economic risks and uncertainties through continuing research, and the level of interest generated in the concept by the government and private sectors.

1. INTRODUCTION

The major objective of this report is to assess the competitive position of fuelwood from proposed energy plantations in Newfoundland. It is generally acknowledged that energy plantations will only be considered a viable energy source when the cost of energy generated from plantation biomass is equal or lower than the cost of alternative fuels. In this report, an estimate of the cost of steam generated through the combustion of biomass from hypothetical energy plantations in Newfoundland is developed and compared with the cost of steam generated from biomass from non-commercial forests and fuel oil. The assessment is based on a "usable energy" approach taking into account the heat value and cost of each feedstock as well the cost configuration and efficiency of the system recovering energy from the feedstock.

Energy plantations are based on the establishment and intensive management of selected trees grown under short rotations specifically as an energy crop. The concept is more closely related to agricultural production than to traditional forestry as many techniques developed for agricultural row crops are applied. The production of wood is normally concentrated near conversion centres in order to minimize transportation costs.

The concept of energy plantations is not new as Europeans were managing hardwoods for fuelwood on a short coppice rotation several hundred years ago.[1] Renewed interest in energy plantations as an alternative source of fuel occurred in the early seventies during the oil crisis when the price of fossil fuels increased dramatically and forced many countries to seriously review their energy options. Interest in the concept has decreased somewhat in recent years due to a marked decline in the price of fossil fuels, nevertheless, consideration continues to be given to the potential role energy plantations could assume as a source of domestic and renewable energy feedstocks in regions that lack conventional fuels.

Energy plantation research in Newfoundland commenced in 1982 as an offshoot of a program evaluating the use of willows for agroforestry and community shelterbelts.[2] Willows have been extensively utilized in Swedish energy plantation research programs and have been proven as suitable candidates for use in plantations in cool boreal forest regions. Funding for the energy plantation research in Newfoundland was provided by the ENFOR program administered by the Canadian Forestry Service.

Field trials of willows commenced at the Pasadena nursery in western Newfoundland where preliminary yields reached 28.5 tonnes dm/ha/a.[3] The program has been expanded in recent years to include four sites in central Newfoundland and one in eastern Newfoundland.[4] Research findings have indicated that 8 to 11 tonnes dm/ha/a could be considered a practical production rate under field conditions in western and central Newfoundland.[5]

Alternate fuels and, in particular, wood fuels have played an important role in Newfoundland in reducing the demand for conventional fuels. In 1983, wood fuels met 25 percent of the residential energy demand and approximately 6 percent of the provincial energy demand.[6] The pulp and paper industry is presently the largest industrial consumer of wood fuels.

The federal and the provincial government in Newfoundland have jointly promoted the use of fuelwood as a substitute for imported oil. Efforts have been made to develop a commercial fuelwood industry based on biomass harvested from non-commercial timber stands. The biomass would be utilized as a replacement for imported oil in commercial and industrial enterprises generating steam for process and space heating requirements. Several demonstration projects promoting the use of fuelwood to generate steam in boilers have been successfully implemented under the Canadian-Newfoundland Energy Conservation and Renewable Energy Program. Examples of these projects include the installation of wood fired steam generating boilers at the Jame Paton Memorial Hospital in Gander and the Newfoundland Hardwoods Ltd. asphalt and creosote plant in Clarenville.

Studies conducted by the government have indicated that approximately 150 boiler plants individually utilizing over ten thousand gallons of oil annually are located in close proximity to fuelwood sources.[7] It is anticipated that a number of these plants could provide markets for fuelwood from energy plantations in the future.

The report commences with a brief overview of the current status of energy plantation research in Sweden, United States and central Canada. Following this review, the methodology of the study is presented. In the next section, cost estimates of the major energy plantation operations are developed and presented with cost estimates of alternative feedstocks. An economic analysis based on the generation of steam in package boilers is developed in the following section. The impact of changes to major variables such as feedstock costs are examined by sensitivity analysis. In the concluding chapters, an assessment is made of the prospects for biomass from hypothetical energy plantations vis-a-vis alternative fuels.

2. ENERGY PLANTATION OVERVIEW

2.1 GENERAL

A brief overview of the state of energy plantation research and development in Sweden, United States and central Canada is presented in this chapter. The discussion is primarily centered on current developments including recent plantation cost estimates.

2.2 SWEDEN

Since the oil crisis in 1973, Sweden has been striving to find replacements for imported oil through the utilization of domestic energy sources. Attempts to increase the use of alternative fuels have been strengthened by the long term objective of phasing out nuclear energy. Over the past decade, energy plantations have been seriously considered as a potential source of biomass for energy.

A major energy plantation research project commenced in 1976 under the direction of Professor Gustaf Siren at the Swedish University of Agricultural Sciences. The project is part of a research and development program funded by the National Energy Administration. A major objective of the program is to assist in the development of viable energy conversion systems based on energy plantation biomass by the 1990's.[8]

Energy plantation research at the Swedish University of Agricultural Sciences is primarily concentrated on willows although, in the future, increased attention may be given to alder (Alnus incana) and poplar (Populus spp.) Research findings have indicated that yields of over 20 tonnes dm/ha/a are common in experimental plots, however, yields in the order of 15 tonnes dm/ha/a are anticipated in commercial operations on agricultural land.[9]

The intention in Sweden is to establish energy plantations in the southern and central regions on surplus agricultural land. Approximately 1.0 to 1.5 million hectares of land are considered to be available for energy forestry.[10] According to National Energy Administration estimates, fuel production from energy forests on agricultural land could reach the equivalent of 7 TWh by the year 2000.[11]

Energy plantations are still in the early development stage in Sweden. The farming community is expected to provide the main thrust of development as limited industrial interest has been expressed. Small farmers cultivating areas of 15 to 20 hectares would utilize their own farming equipment and hire specialized machinery currently under development and additional labour.

There are no commercial scale energy plantations in Sweden at present, however, four large-scale research plantations and a number of smaller plantations under private management are in operation.[12] The major objective of many of these operations is to examine the economic viability of small scale energy forests. An example of this type of development is the joint venture by Southern Sweden Power Supply Company

(Sydkraft) and the Agricultural Society of Malmohus County establishing experimental plantations principally on agricultural land in Skane and southern Halland.

At present, wood fuels in Sweden are experiencing difficulty competing with coal and electric power. Recent estimates suggest that chipped energy plantation biomass could be delivered to a conversion plant for approximately 105 SEK/MWh.[13] It is assumed that, over the long term, increases in the price of conventional energy will enhance the competitiveness of traditional wood fuels and peat. Recent forecasts indicate that the price of coal may be approximately 85-90 SEK/MWh (1984 SEK) in the mid 1990's compared to 75-95 SEK/MWh for biomass from energy plantations located on agricultural land.[14] It is anticipated that the establishment of major energy plantations in Sweden will not occur until at least the mid 1990's.

2.3 UNITED STATES

Energy plantation research in the United States is primarily conducted through the Short Rotation Woody Crops Program (SRWCP) sponsored by the Biofuels and Municipal Waste Technology Division of the Department of Energy. Initiated in 1979, the program is designed to improve the technical information base of short rotation plantations through field research experiments, laboratory testing and analyses. The Department of Energy is also supporting research programmes in the biochemical and thermochemical conversion of wood to liquid and gaseous fuels. In addition to the programs sponsored by the Department of Energy, research and small field trials have been initiated by the U.S. Forest Service, universities and the private sector.

The economic challenge in the Short Rotation Woody Crops Program is centered on the development of a competitive renewable energy production system. In the future, biomass from the energy plantations could be used as a feedstock in the production of liquid and gaseous fuels which would reduce demand for petroleum based fuels. Attention is currently being concentrated on growing conditions in the Lake States, Southeast, Northeast, Pacific Northwest and the subtropics (southern Florida and Hawaii) where conditions are more favourable for plantation development.[15]

Research in the SRWC program has concentrated on the selection and improvement of suitable species and cultural practices in order to increase productivity on marginal to good surplus agricultural land. Attention is currently being paid to 22 of the 125 candidate species evaluated since 1978.[16] Research is focussed on determining the natural variation within these species as well as opportunities for genetic improvement. Approximately sixty percent of the research activities in the SRWC program are currently concentrated on the genus Populus.[17]

Research in the United States has shown that the energy plantation concept is technically feasible and costs are potentially competitive under proper conditions. However, further research is required before the technology is ready for commercialization. Delivered cost estimates for biomass from hypothetical energy plantations in the United States using available technology range from U.S. $3.00 per GJ to U.S $4.10 per GJ.[18] The goal of the SRWC program is to reach an average productivity of 20 tonnes dm/ha/a at a cost of U.S. $2.25 per GJ (1985$) on the best research plots in the United States by 1995 and develop a competitive technology by the year 2000.[19] The price of coal in the year 2000 is forecast to range from U.S. $2.25 to $2.40 per GJ (1985$) for industrial and commercial consumers.[20] Further

improvements in the cost structure of energy plantations will depend, in part, on physiological and genetic research to increase productivity and site adaptability of tree crops and reduce silvicultural costs.

Some interest in the energy plantation concept has been expressed by the private sector in the United States. Researchers at universities and government agencies are working directly with industry at nine locations examining the viability of experimental plantations sized at forty hectares and larger.[21] Scott Paper is undertaking 10 acre trials of short rotation plantations and is currently considering the development of a 50 hectare parcel solely for energy.[22] Northern States Power Company is conducting trials with the objective of selecting clones which could eventually supply a 400 MW wood fired boiler.[23] This company is also considering the development of a 50 MW wood fired boiler demonstration project supplied by farmers establishing energy plantations on 10,000 hectares of agricultural land. Little emphasis is being placed on the design of specialized equipment for energy plantations in the United States.

2.4 CENTRAL CANADA

Interest in energy plantation research in Canada peaked when fossil fuel prices increased during the 1970's and early 1980's, however, attention and funding waned in recent years when the price of conventional fuels declined. In general, more emphasis has been placed in central Canada on energy conservation and the use of forest industry residues as a feedstock than on research directed to the development of energy plantations.

During the first half of the 1980's, the Bioenergy Program of the National Research Council (NRCC) provided leadership in the research and development of specialized systems and equipment required to mechanize short rotation plantation operations in regions such as Eastern Ontario. The majority of research on the systems was conducted over the period 1982 to 1985. Due to funding constraints, the project was terminated in 1986.

The study of the biophysical aspects of short rotation plantations in the program provided data required for the design of high productivity machinery. The development of the NRCC FB7 harvester capable of harvesting up to one thousand trees per hour represented a major advance in the provision of specialized equipment for short rotation plantations. Approximately two more years of research and development activity would be required to complete the task of developing the full range of short rotation plantation equipment examined during the program.[24]

NRCC research and development activities on energy plantations led to the publication of the NRCC report "Analysis of Short Rotation Plantation Operations."[25] The report provides a detailed analysis of short rotation plantation operations based on hybrid poplar plantations in eastern Ontario. Cost analyses were based on the concepts and specialized prototype machinery developed by the project. The delivered cost of biomass from the hypothetical plantations was estimated at $56.47 per ODT (1985$) for a two year rotation plantation with a yield of 20 tonnes per hectare, $31.76 per ODT for a five rotation plantation with a yield of 50 tonnes per hectare and $30.78 per ODT for a ten year rotation plantation based on a yield of 62 tonnes per

hectare. The model developed in the NRCC publication is used in this report as a base for estimating the cost of energy plantation biomass in Newfoundland.

Short rotation plantations in central Canada are predominantly based on hybrid poplar. Hybrid poplar research in Canada has been conducted over the past forty to fifty years.[26] In 1978, the Ontario Ministry of Natural Resources and the federal government, through the Department of Regional Economic Expansion (DREE), commenced the joint funding of a research program centered on the development of hybrid poplar plantations. Approximately 40,000 hectares of marginal and idle farmland suited to hybrid poplar production has been idenfified in eastern Ontario alone.[27] New hybrids have been developed through the program that are specifically adapted to the soils and climatic conditions of Ontario.

The first production scale plantations of hybrid poplar were established in eastern Ontario in 1972 in response to a diminishing pulpwood resource supporting Domtar pulp and paper operations.[28] Hybrid poplar plantations in Ontario presently cover 3,000 hectares.[29] The market price for poplar pulpwood at mill gate is in the order of $56 per ODT.[30] Although the plantations are currently established for pulpwood production, techniques and knowledge accumulated through the research program and commercial operations could be readily applied to future development of energy plantations.

3. METHODOLOGY

The major objective of this report is to evaluate the competitive position of fuelwood from proposed energy plantations in Newfoundland relative to competitive fuels. The three fuels examined are:

1. Energy plantation biomass

2. Non-commmercial forest biomass

3. Fuel Oil

The methodology incorporates a total energy system approach to enable a comparison to be made between feedstocks on a "usable energy" basis. The "usable energy" approach takes into account the heat value and costs of each feedstock as well as the efficiency and costs of converting the feedstocks into energy.

The report commences with the development of cost estimates for each feedstock. An estimate of the delivered cost of wood from hypothetical energy plantations in Newfoundland is developed through the use of a model prepared by T.B Golob for the National Research Council of Canada as described in the 1986 NRCC publication "Analysis of Short Rotation Forest Operations."[31] The model provides detailed analyses of fully mechanized hypothetical energy plantation operations based on studies and development work undertaken by the Bioenergy Program of the NRCC. Plantation operations are based on the utilization of specialized equipment which was under various stages of development in the NRCC program and considered to be technically feasible. The equipment requires further development and is not

commercially available at present. It is widely acknowledged that specialized machinery is normally required for an economically viable energy plantation operation in a developed economy as plantation operations are generally labour intensive.

The NRCC analysis of short rotation energy plantations is based on the development of poplar plantations in eastern Ontario under 1985 cost and price levels. In this report, the NRCC model is used to develop an estimate of the cost of biomass from hypothetical energy plantations in central Newfoundland under mid 1987 cost and price levels. The cost analysis includes all plantation operations from site preparation to the delivery of biomass to the final conversion point. Major cost components are as follows:

. site preparation

. nursery operation

. planting

. tending

. harvesting

. chipping and transport

. administration and overhead

A number of adjustments are made to the NRCC model and analyses to conform with biological factors and cost elements common to Newfoundland. Major adjustments include:

. Labour costs are adjusted to reflect labour rates for similar positions in Newfoundland in mid 1987. An average hourly labour rate of $13.50 plus 25% burden is used in the analysis.

. Machinery prices and the cost of fuel, operating supplies and repairs are adjusted to reflect 1987 cost and price levels.

. Biomass yields from the energy plantations are adjusted to reflect biological conditions in Newfoundland.

. Adjustments are made to the productivity of harvesting and chipping operations to reflect smaller tree size and reduced biomass yield in Newfoundland.

. An allowance for administrative and overhead costs is included in the Newfoundland cost estimate.

The cost of the alternative feedstocks, fuelwood from non-commercial forests and fuel oil, are based on average fuel prices in central Newfoundland for medium sized commercial and industrial consumers during mid 1987.

Recovering the energy value from fuelwood normally involves either direct combustion or conversion to gaseous or solid fuels followed by combustion. The analysis in this report is based on the direct combustion of fuelwood to generate steam, one of the most widely used commercial processing routes for fuelwood. The technology for generating steam is well established and relatively uncomplicated.

The conversion system is based on the generation of steam in package boilers. The process heat load for the system is assumed to be 13.4 GJ/h. Major operating parameters as well as capital and operating costs are developed for a wood fired boiler and a fossil fuel fired boiler. Based on this data, estimates of the cost of energy produced from each feedstock are developed and expressed in terms of dollars per gigajoule of usable energy output. A preliminary assessment of the viability of energy plantations in Newfoundland is based on these estimates.

4. FEEDSTOCK COST ESTIMATES

4.1 GENERAL

The cost of the three feedstocks used for the generation of steam in the energy system are developed in this section. The three feedstocks are as follows:

- biomass from hypothetical energy plantations
- biomass from natural non-commercial forests
- fuel oil (#6)

4.2 ENERGY PLANTATION BIOMASS

As discussed previously, the development of a cost estimate for fuelwood from hypothetical energy plantations located in central Newfoundland is based upon a model outlined in the NRCC publication "Analysis of Short Rotation Forest Operations." Data entering the model has been adjusted to suit conditions and costs found in Newfoundland as described in the preceding section on methodology. It is important to note that the specialized equipment which provides the base for the estimates is not commercially available at present.

The design concepts for the hypothetical plantations and cost estimates for each plantation operation follows. Detailed analyses of each operation as well as the methodology for the economic analysis are found in the NRCC publication noted above.

4.2.1 Plantation Design

It is assumed that the energy plantations will be based on the establishment of willows as they are presently being examined in plantation trials in Newfoundland. Willows are close relatives to poplars which the NRCC based their hypothetical plantations in eastern Ontario upon. The characteristics of willows meet standard

criteria for use in energy plantations which center on rapid early growth, wide site adaptability, high tolerance to environmental stress, coppicing ability and high biomass productivity.[32] A major benefit of willows is their ability to be vegetatively propagated through stem cuttings. According to research carried out by Robertson, willows are more suited to Newfoundland conditions than poplar.[33]

Plantation fuelwood costs are developed over one establishment rotation and three coppice rotations. Utilization of the coppice rotations will eliminate costs associated with replanting after each harvest. The rotation age of the plantations is assumed to be five years. Each plantation is sized at 20 hectares with a stand density of 4,000 stems per hectare (1.5 x 1.5 metres). This density conforms with the trend away from very close spacing where the initial cost of establishment and mortality of stems is high and, in the case of most species, the resulting productivity is not significantly different from that obtained at lower planting densities.[34] Experimental trials in Newfoundland have also confirmed these results.[35]

It is assumed that the energy plantations are established on medium quality forest cutovers in central Newfoundland. It should be noted that the energy plantation program in Sweden and the United States is based upon the use of under-utilized agricultural land. As the program in Newfoundland is primarily based on the utilization of forest land, major adjustments must be made to reflect the increased cost of establishing plantations on less desirable land.

The economic viability of energy plantations is greatly influenced by biomass yields. Short rotation plantation research has shown that yields are highly dependent on clone, spacing density, rotation length, site conditions, intensity of management and the number of times the crop has been coppiced.[36] At present, information on yields is mainly based on small experimental research plots. Little data is available on commercial scale operations in the boreal regions.

An economic analysis of biomass from energy plantations in Sweden, which has many similarities in growing conditions with Newfoundland, used an average annual yield of 12 tonnes dm per hectare.[37] Researchers in the United States have documented average yields of 9 to 12 tonnes dm/ha/a over a wide range of sites.[38] In the Lake States in northern United States, yields from first rotation growth have averaged 8.0 tonnes dm/ha/a and coppice growth 9.2 tonnes dm/ha/a.[39]

The NRCC selected an average annual yield of 10 tonnes dm/ha/a for the economic analysis of their base case five year rotation plantation. Yields of 28.5 tonnes dm/ha/a have been documented at trials at the Pasadena nursery in Newfoundland, however, these results are a product of carefully tended nursery research plots.[40] In the opinion of Robertson, average yields of 8 to 11 tonnes dm/ha/a could be expected with selected willow clones in Newfoundland.[41]

Taking into consideration the above estimates, a conservative average yield of 8 tonnes dm/ha/a is assumed for the hypothetical plantations developed in this report. The impact of a higher yield is assessed in the sensitivity analysis. It is anticipated that genetic improvements will lead to higher yields in the future.

Cost estimates for the major plantation operations follow.

4.2.2 Site Preparation Costs

Proper site preparation is critical to successful plantation establishment and the attainment of acceptable yields. Site preparation techniques for energy plantations are very similar to those required for an agricultural crop. The operations normally encompass ground cover removal, collection of roots, stumps and stones, plowing, discing, harrowing and application of herbicides.

It is assumed that energy plantations in Newfoundland would be located on Crown forest land supporting cutover stands. Prior to the site preparation operation, the forest cover would be harvested, chipped and sold as pulpwood or fuelwood. Costs and revenues from this operation are excluded from the energy plantation analyses.

The cost of site preparation varies greatly according to the terrain, nature of vegetation to be removed and soil conditions. In the NRCC plantation analysis for eastern Ontario, site preparation costs were based on the rehabilitation of brush covered marginal agricultural land. As energy plantations in Newfoundland would normally be located on forest land characterized by stumps and surface stoniness, the site preparation operation is more complex.

In accordance with the NRCC plantation analysis, specialized equipment for this operation would consist of a brush harvesting machine and a root, stump and stone collector. Land clearing would be followed by ploughing, discing, harrowing and the application of herbicides through the use of conventional agricultural equipment.

Assuming that the specialized equipment proposed by the NRCC would be suitable for sites within Newfoundland or could be modified at minimal expense, the productivity for the system estimated by the NRCC at 0.4 ha/PMH for eastern Ontario is reduced by 30% to reflect site conditions found in Newfoundland. On this basis, site preparation costs in Newfoundland are $1,600 per hectare compared to $998 per hectare in Ontario.

No allowance has been made for the cost of leasing Crown land from the Newfoundland government. It is assumed that this charge would be minor as marginal forest land would be utilized.

The impact of site preparation costs is lessened somewhat by distributing the cost over four harvests. Land preparation costs in Newfoundland on a oven dry tonne of biomass basis are $15.50. For comparison purposes, land preparation costs in eastern Ontario were estimated by the NRCC to be $8.28 per oven dry tonne of biomass.

4.2.3 Nursery Costs

Energy plantations based on willows are normally established with stem cuttings which are considered to be the most flexible and least expensive planting stock.[42] The total cost of nursery operations in the NRCC model is comprised of the cost of establishing a whip plantation planted at a stand density of 33,000 whips per hectare, harvesting and delivering the whips to a production plant designed to produce cuttings from the whips and the production and storage of cuttings which will be used to establish the plantations.

As this operation can be very labour intensive, the NRCC analyses are based on the use of specialized equipment consisting of a whip harvestor and a fully mechanized operation for the production, handling and storage of cuttings. The specific machinery envisaged by the NRCC for this operation is still in the development phase.

Nursery operation costs are prorated over the four rotations. The cost of the nursery operations in Newfoundland is $1.15 per oven dry tonne of biomass compared to $0.82 per oven dry tonne estimated by the NRCC for eastern Ontario.

4.2.4 Planting Costs

The planting operation consists of the transport of magazines filled with cuttings from the nursery to the plantation site and the planting of cuttings. Specialized equipment for this operation is based on the development of a six row planting machine capable of planting 1.7 ha/PMh.

Based on the productivity of the six row planter, planting costs in Newfoundland are $154 per hectare. Distributing the planting costs over the four rotations assumed in the model, the cost of planting is $1.55 per oven dry tonne of biomass. This expenditure is similar to planting costs in Ontario which were estimated by the NRCC to be $1.17 per oven dry tonne.

4.2.5 Tending Costs

The tending operation is based on a mechanical weed control operation in the third year of each rotation. Equipment for this operation consists of a tractor and a modified cultivating implement.

This operation does not include fertilization. Based on the assumptions outlined in the NRCC study, the reduction in the cost per tonne of biomass resulting from increased yields through the application of fertilizer was not significant. However, experimental trials in Newfoundland suggest that fertilization will be necessary to maintain yields over successive rotations.[43]

Irrigation is also excluded. According to research in the United States, the cost of irrigation usually exceeds the value of incremental production in the Northeast and Lake States where drought conditions only occur occasionally.[44] In the opinion of Robertson, irrigation would not be cost effective in Newfoundland.[45]

The cost of mechanical tending in Newfoundland is estimated at $100 per hectare. As the benefits of the tending operation are primarily limited to one harvest, the cost of this operation is applied to a single rotation and is compounded from the third year of the rotation when the tending operation occurs to the time of the next harvest.

The total cost of the tending operation including transport of equipment to the site is $3.10 per oven dry tonne of biomass. In comparison, the cost of a similar operation in eastern Ontario was estimated by the NRCC to total $2.22 per oven dry tonne.

4.2.6 Harvesting Costs

The harvesting operation consists of the harvesting and transport of biomass to a storage area at roadside. Costs for this operation are based on the commercial availability of specialized harvesters in the future. Other equipment in this operation such as tractors required for the harvesting and forwarding operation are currently available on the commercial market. The harvesting operation is timed to commence after leaf fall when the plantation is in a dormant stage.

Harvesting operations represent a significant cost element in energy plantations and, as a result, innovative equipment is required to reduce the cost of harvesting smaller trees. As the diameter of the trees harvested decreases, the number of stems harvested per unit of time must increase geometrically if production is to remain constant.[46] Conventional harvesting equipment is designed for single stem trees usually greater than 20 cm (8 in.) dbh and is usually inefficient for falling smaller trees of 5 to 20 cm. (2 to 8 in.) dbh.[47] Furthermore, multiple stems produced by coppicing and the biological requirement for relatively smooth split-free stumps required for coppice growth provide additional challenges in equipment design.

A survey and analysis by Curtin and Barnett reviewed eleven prototype harvesting machines developed specifically for energy plantation use.[48] The machines, which were developed through government agency support in Canada, Ireland, Sweden and the United States, are in various stages of development and are predominantly designed as attachments to agricultural tractors.

Harvesting costs in the NRCC report are based upon three prototype harvesters studied during the NRCC Bioenergy Program. Due to the different characteristics of each crop, separate harvestors were conceptualized for harvesting the whip plantation, the first rotation crop and the coppice crop. Costs for harvesting the first rotation crop are based on the future development of a four row harvester modeled after the single row FB7 continuous feller buncher developed by the NRCC and considered a commercially acceptable machine.

As the harvesting costs developed by the NRCC for eastern Ontario are based on yields of 50 oven dry tonnes per hectare compared to 40 tonnes for Newfoundland, the productivity of the harvesting operation has been modified to account for the smaller trees and yields from the hypothetical plantations in Newfoundland. The productivity of the harvesting operation has been reduced from 61 ODT/PMh in eastern Ontario to 50 ODT/PMh in Newfoundland. Similar to the preceding operations, allowances are made for cost of transporting the harvesting equipment to and from the 20 hectare plantation sites.

The cost of harvesting biomass from energy plantations in Newfoundland is $8.20 per oven dry tonne. The cost of the same operation in southern Ontario was estimated by the NRCC to be $6.23 per oven dry tonne. The higher cost in Newfoundland is predominantly attributable to smaller tree sizes and hence lower productivity.

4.2.7 Chipping and Transport

The chipping and transport operation is based on a conventional approach with commercially available equipment. Biomass stockpiled by the roadside at the plantation

site is fed into a mobile self-propelled chipper, blown into 14 metre trailors and transported to the conversion plant. As the low energy density of the fuel results in high transportation costs, the plantation must be located fairly close to the conversion plant. It is assumed that the average distance to the conversion plant is 30 kilometres and the average load per trailor is 32 green tonnes. To facilitate transport scheduling, an allowance has been made for a support tractor and spare trailors at the plantation landing.

The feeding efficiency of the chipper has been reduced from 60 percent cited in the NRCC study to 50 percent to account for the smaller size of trees in the Newfoundland plantation. Consequently, the chipper productivity in Newfoundland is reduced to 22.5 ODT/PMh. The total cost of the chipping operation in Newfoundland is $9.30 per oven dry tonne compared to the NRCC estimate of $7.29 per oven dry tonne for Ontario.

The cost of transporting chips to the conversion point is $6.20 per oven dry tonne. This estimate is slightly higher than the transport cost developed by NRCC for the plantation in eastern Ontario.

Chipping is the conventional approach of reducing biomass to a relatively uniform particle size. In the future increased attention will be paid to recent developments in chunking and crushing biomass. Both processes are less energy intensive than chipping and lead to improved drying and reduced heat buildup in stockpiles. Energy requirements for chunking are approximately 35 percent of those required for chipping.[49]

Northern States Power Company of Minnesota is considering the development of a furnace for power generation which utilizes biomass in roundwood form thus eliminating costs associated with chipping.[50] These developments will likely assist in reducing biomass handling costs in the future.

4.2.8 Administrative and Overhead Costs

This cost category provides an allowance for profit and costs associated with plantation management, general administration, research, insurance, taxes (muncipal, provincial and federal) and miscellaneous expenses such as monitoring for disease prevention and snow clearing. The allowance for these items is 20 percent of the cost of the preceding operations and is equivalent to $9.00 per ODT. This allowance was not included in the NRCC study for eastern Ontario.

4.2.9 Summary of Energy Plantation Costs

A summary of the energy plantation cost estimates developed for central Newfoundland is shown in Table 1 and Figure 1. For comparison purposes, the corresponding costs developed by the NRCC for five year rotation plantations in eastern Ontario are also presented.

Table 1
Summary of Energy Plantation Costs
(dollars per oven dry tonne)

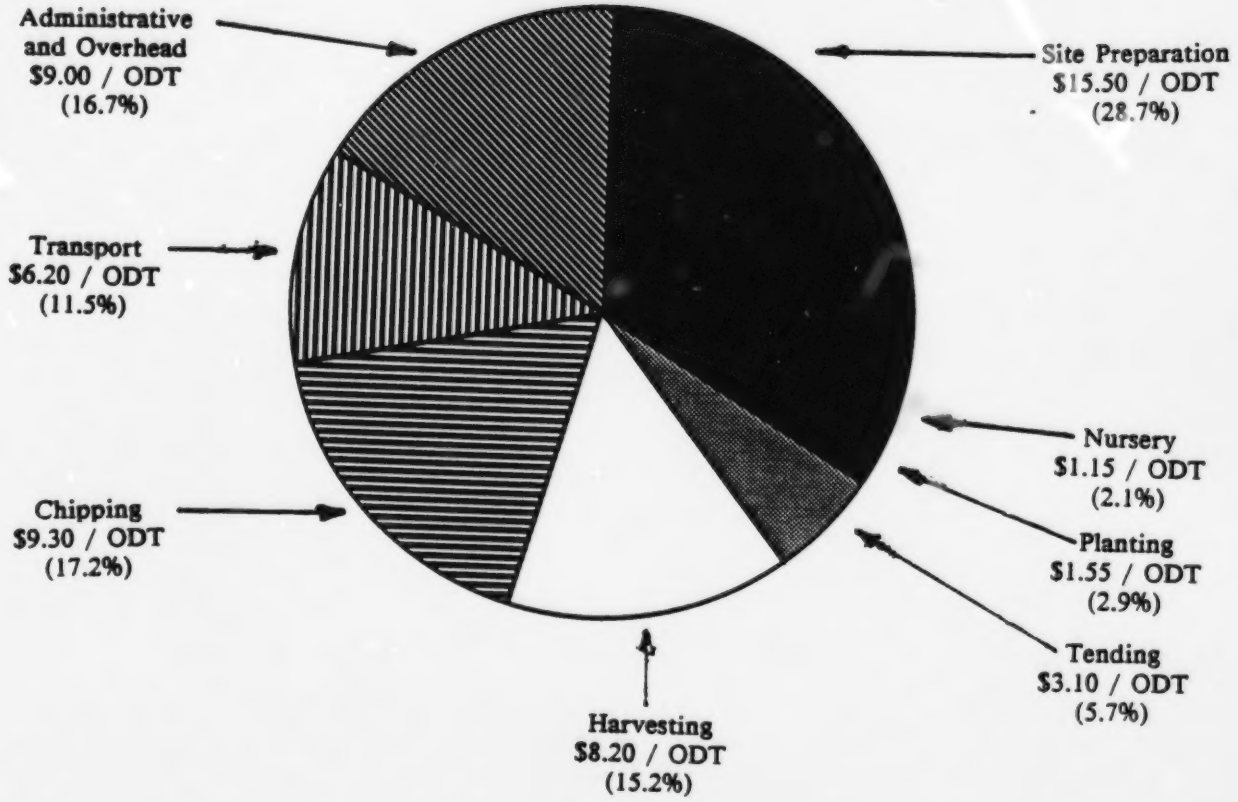
	Central Newfoundland		Eastern Ontario	
	$/odt	percent of total	$/odt	percent of total
Site Preparation	15.50	28.7	8.28	26.1
Nursery	1.15	2.1	0.82	2.6
Planting	1.55	2.9	1.17	3.7
Tending	3.10	5.7	2.22	7.0
Harvesting	8.20	15.2	6.23	19.6
Chipping	9.30	17.2	7.29	22.9
Transport	6.20	11.5	5.74	18.1
Administrative and Overhead	9.00	16.7	-	-
Total Cost	54.00	100.0	31.76	100.0

Note: Estimates for Newfoundland are based on mid 1987 cost levels. NRCC estimates for eastern Ontario are based on 1985 costs.

Figure 1

Newfoundland

Cost Estimates of Major Energy Plantation Operations



Source: Table 1

The total cost estimate of biomass delivered to a conversion plant from hypothetical energy plantations in central Newfoundland is $54 per oven dry tonne. This estimate is 70 percent greater than the corresponding estimate developed by the NRCC for eastern Ontario. In the opinion of Robertson, the cost of biomass from energy plantations in eastern Newfoundland may be less than the cost estimate developed in this report for central Newfoundland due to superior quality of sites in eastern Newfoundland.[51]

4.3 NON-COMMERCIAL FOREST BIOMASS

Non-commercial forest biomass refers to whole tree wood chips harvested from insect damaged, fire damaged, scrub, hardwood and residual cutover stands in central Newfoundland. The estimated price of fuelwood chips delivered to a hypothetical conversion plant in mid 1987 is $32 per tonne (45% mc). This estimate is based on contract prices negotiated by the commercial fuelwood industry in central Newfoundland.[52]

4.4 FUEL OIL

The price of #6 fuel oil delivered to a hypothetical conversion plant in central Newfoundland is $0.28 per litre. This estimate is based on price levels in mid 1987 for medium size industrial and commercial consumers in central Newfoundland.[53]

5. ENERGY SYSTEM ANALYSIS

An economic analysis of the energy conversion system is presented in this section. The conversion system consists of a wood fired boiler and a fossil fuel fired boiler used for the generation of steam. The feedstock for the wood fired boiler is assumed to be obtained from two sources; biomass from the hypothetical energy plantations described earlier in the report and biomass from non-commercial natural forest stands. The feed-stock for the fossil fuel fired boiler is assumed to be #6 fuel oil. The objective of the analysis is to compare the cost of steam generated through the combustion of each feedstock.

For the purpose of the analysis, it is assumed that the process heat load for the three cases is 13.4 GJ/h. In each case, the heat load is met through the generation of low pressure steam in a package boiler. The major operating parameters of the two boiler systems are as follows:

Table 2
Basic Operating Parameters
Wood and Oil Fired Boilers

System Output	
Steam	1.14 kg/s
Steam temperature	185°C
Steam pressure	1034 kPa
Operating days	350 days/a
Operating hours per day	24
Load factor	70%
Operating efficiency	
Wood fired boiler	65%
Oil fired boiler	80%
Annual fuel requirements	
Wood fired boiler (wood chips - 45% m.c. wet basis)	12,000 tonnes
Fossil fuel fired boiler (#6 fuel oil)	2,138 tonnes

Capital cost estimates for a wood fired boiler and a oil fired boiler are summarized in Table 3. The costs are site specific for central Newfoundland and are based on quotes from suppliers and data from the consultant's reference files.

Table 3
Capital Cost Estimates
Wood and Oil Fired Boilers
(thousand dollars)

	Wood Fired Boiler	Oil Fired Boiler
Structures	60	40
Equipment	620	228
Installation	150	55
Contingencies	83	32
Direct Capital	913	355
Indirect Capital	59	25
Total Capital Cost	972	380

Notes:

1. Structures excludes land cost, site preparation and site services.

2. Indirect capital includes engineering, project management, pre-operating and start-up expenses and interest during construction. Working capital is excluded.

As shown in Table 3, capital costs for a wood fired boiler are considerably greater than an oil fired boiler with an equivalent thermal capacity. The higher cost is predominantly attributable to the larger size of the wood fired boiler as well as additional equipment required for feedstock handling and ash disposal. The heating value of woody biomass on a bone dry basis is comparatively low compared to fossil fuels and is further reduced as moisture content increases. As the heat release rates are lower for wood fuels, a much larger combustion chamber is required for the equivalent steam output.

Annualized capital costs for the two boilers are developed through the use of the following equation.

$$\text{Annualized capital cost} = \text{Capital cost} \times \frac{r}{1 - (1 + r)^{-n}}$$

where r = discount rate
n = life of the plant

The annualized capital cost provides for the recovery of the full value of the investment over the life of the plant. The capital cost is annualized over the life of the plant, assumed to be 20 years, at a real discount rate of 7 percent.

Based on the above assumptions, the annualized capital costs of the package boilers are as follows:

Wood fired boiler	$91,400
Oil fired boiler	$35,700

Annual operating costs for the two boilers are summarized in Table 4. Operating costs are based on performance data obtained from equipment suppliers and engineering consultants.

Table 4
Annual Operating Cost Estimates
Wood and Oil Fired Boilers
(thousand dollars)

	Wood Fired Boiler	Oil Fired Boiler
Labour - Operating & Maintenance	232	187
Electric Power	9	5
Miscellaneous	27	12
Total Operating Costs	268	204

Note: Misc. includes operating and maintenance supplies, property tax, insurance and overhead costs.

Operating costs for the wood fired system are greater than costs for the oil fired system. The increased cost reflects higher labour inputs particularly for feedstock handling and ash disposal operations as well as increased maintenance costs.

Feedstock requirements and costs for the boiler systems are presented in Table 5.

Table 5
Feedstock Requirements and Cost Estimates

	Annual Requirements (tonnes)	Unit Cost	Annual Cost (thousand dollars)
Wood Fired Boiler			
Energy Plantation Biomass (45% m.c.)	12,000	$32.25 / tonne	387
Non-commercial Forest Biomass (45% m.c.)	12,000	$32.00 / tonne	384
Oil Fired Boiler			
Fuel Oil - #6	2,138	$ 0.28 / litre	624

A summary of annual capital, operating and feedstock costs for each boiler system is shown in the following table.

Table 6
Summary of Annual Capital, Operating and Feedstock Costs
Wood and Oil Fired Boilers
(thousand dollars per annum)

	Wood Fired Boiler		Oil Fired Boiler
	Energy Plantation Biomass	Natural Forest Biomass	Fuel Oil #6
Annualized Capital Cost	91	91	36
Annual Operating Cost	268	268	204
Annual Feedstock Cost	387	384	624
Total Annual Costs	746	743	864

As shown in Table 6, the wood fired boilers provide the lowest annual cost in the generation of steam. The lower feedstock costs for the wood fired boilers more than offset the higher capital and operating costs associated with wood fired boilers.

The cost of energy in the form of steam generated from each feedstock is as follows:

Biomass from Energy Plantations	$ 6.63 / GJ
Biomass from Non-commercial Forests	$ 6.60 / GJ
Fuel Oil (#6)	$ 7.68 / GJ

The cost of steam generated by biomass from hypothetical energy plantations in central Newfoundland is $6.63 per GJ. This estimate is very similar to the cost of steam generated from biomass harvested from non-commercial forest stands in the region. The cost of steam generated from fuel oil is 16 percent greater than steam generated from energy plantation biomass.

Based on the above estimates, the price of plantation biomass could increase from $54 per ODT to $70 per ODT and still remain competitive with fuel oil. Conversely, the price of fuel oil must decrease from $0.28 per litre to below $0.23 per litre to compete with plantation biomass.

6. SENSITIVITY ANALYSIS

The sensitivity of the cost of steam generated from plantation biomass to changes in system costs and plantation yields is evaluated in this section. Table 7 and accompanying Figure 1 presents the impact of changes to the cost of energy plantation biomass and boiler system operating and capital costs on the cost of steam.

As shown in Table 7, the cost of steam is quite sensitive to changes in the cost of biomass from energy plantations. If the cost of biomass increases by 20 percent, the cost of steam rises by 10.3%. A 20 percent increase in the boiler system operating costs leads to a 7.2 percent increase in the cost of steam. The impact of changes to boiler system capital costs is slight. An increase of 20 percent in capital costs increases the cost of steam by only 2.4 percent.

The influence of changes in the cost of major energy plantation operations is shown in Table 8. The most sensitive operation is site preparation where a 20 percent cost increase raises the cost of steam by 3.0 percent. Chipping, administration and overhead, and harvesting costs exert a smaller influence. A 20 percent increase in these costs raises the cost of steam by 1.8, 1.7 and 1.5 percent respectively. The influence of changes to nursery, planting and tending costs is slight.

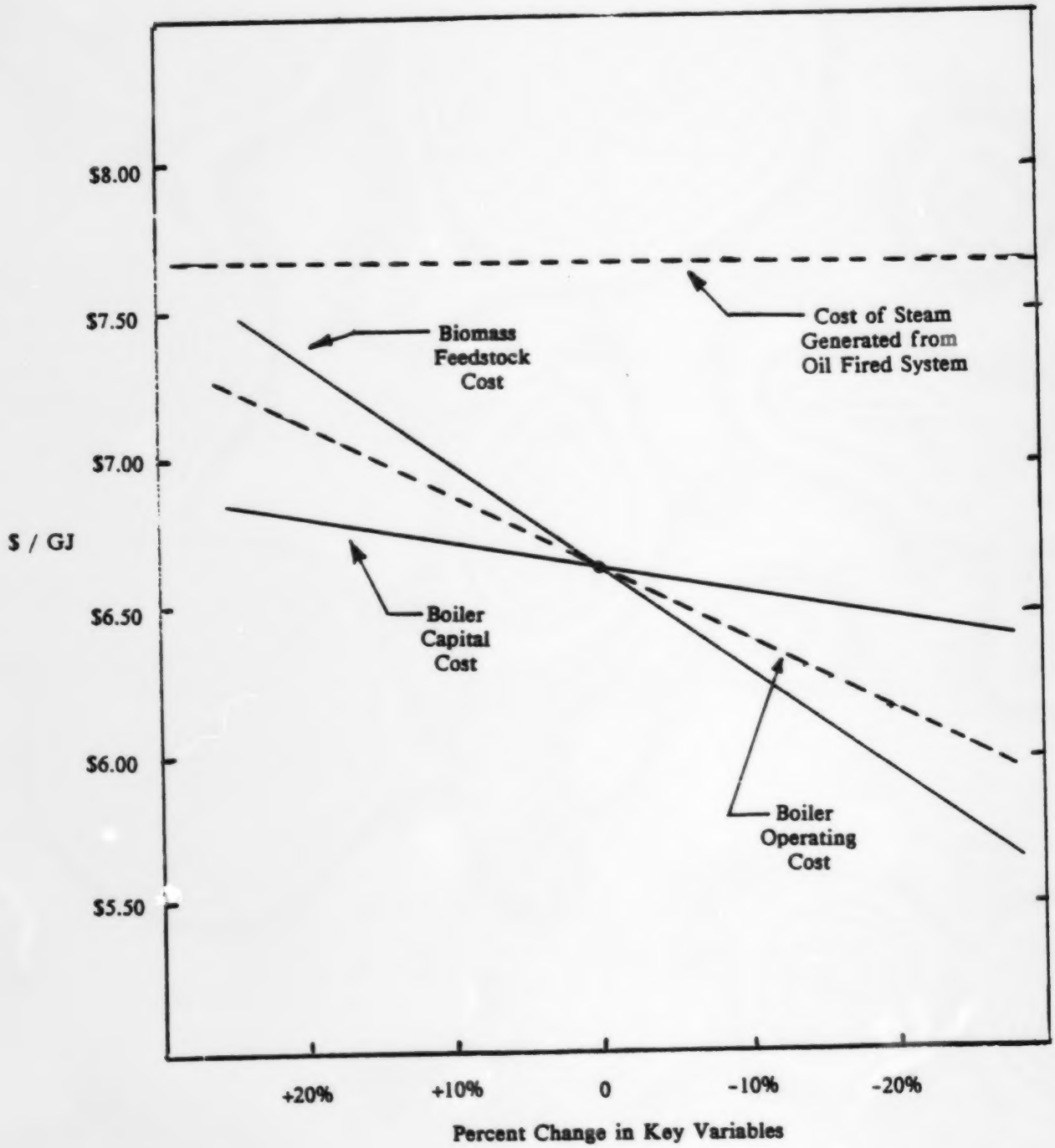
The impact of changes in plantation yields on the economic performance of the energy system is very significant. An increase in plantation yield from 40 tonnes dm/ha in the base case to 50 tonnes dm/ha reduces the delivered cost of energy

plantation biomass from $54 per ODT to $47 per ODT. Furthermore, the cost of steam generated by the system drops to $6.19 per GJ, a reduction of 6.6 percent.

Table 7
Sensitivity of the Cost of Steam Generated
from Plantation Biomass to Changes in Key Variables

	Cost of Steam ($/GJ)	Percent Change from Base Case (percent)
Base Case	6.63	-
Plantation Biomass Feedstock Cost		
+ 20%	7.31	+ 10.3
+ 10%	6.97	+ 5.1
- 10%	6.29	- 5.1
- 20%	5.95	- 10.3
Wood Fired Boiler Capital Cost		
+ 20%	6.79	+ 2.4
+ 10%	6.71	+ 1.2
- 10%	6.55	- 1.2
- 20%	6.47	- 2.4
Wood Fired Boiler Operating Cost		
+ 20%	7.11	+ 7.2
+ 10%	6.87	+ 3.6
- 10%	6.39	- 3.6
- 20%	6.15	- 7.2

Figure 2
Sensitivity of the Cost of Steam Generated from
Plantation Biomass to Changes in Key Variables



Source: Table 7

Table 8
Sensitivity of the Cost of Steam Generated from Plantation Biomass to Changes in Energy Plantation Costs

	Cost of Steam ($/GJ)	Percent Change from Base Case (percent)
Base Case	6.63	-
Site Preparation		
+ 20%	6.83	+ 3.0
- 20%	6.43	- 3.0
Nursery		
+ 20%	6.64	+ 0.2
- 20%	6.62	- 0.2
Planting		
+ 20%	6.65	+ 0.3
- 20%	6.61	- 0.3
Tending		
+ 20%	6.67	+ 0.6
- 20%	6.59	- 0.6
Harvesting		
+ 20%	6.73	+ 1.5
- 20%	6.53	- 1.5
Chipping		
+ 20%	6.75	+ 1.8
- 20%	6.51	- 1.8
Transport		
+ 20%	6.71	+ 1.2
- 20%	6.55	- 1.2
Administration & Overhead		
+ 20%	6.74	+ 1.7
- 20%	6.52	- 1.7

7. ASSESSMENT

The major findings of this report indicate that the cost of biomass from hypothetical energy plantations in central Newfoundland is $54 per ODT. Based on the specific assumptions used in the analysis, the cost of steam generated from energy plant biomass is $6.63 per GJ. This estimate is very similar to the cost of steam generated from biomass harvested from natural forests in central Newfoundland and significantly less than steam generated from fuel oil. Consequently, the findings suggest that, on the basis of current costs and prices, energy plantation biomass could compete with the two major feedstocks used in central Newfoundland for the generation of steam.

In assessing the social and economic contribution energy plantations could provide in Newfoundland, numerous factors with wide ranging impacts must be considered. As commercial energy plantations are still in an early stage of development, assessments of the potential impact are of a tentative nature and must rely on preliminary research findings rather than experience established from ongoing commercial operations.

The potential contribution of energy plantations to the local, regional and national economy is well documented.[54] Major benefits to the economy include:

- Fuelwood from energy plantations would reduce Newfoundland's dependence on imported oil as well as buffer the impact of fluctuating international energy prices. The reduction in imported oil would have a positive impact on balance of payments. Unlike fossil fuels, energy plantations would provide a renewable energy feedstock.

- Plantation wood could provide an alternative to fossil fuels which may have a detrimental effect on the environment. Compared to oil and coal, wood contains little sulphur which can combine with oxygen to form sulphur dioxide, a prime contributor to acid rain.[55]

- An active rural sector is recognized as as essential component of economic development. The development of energy plantations would provide sustainable employment opportunities and incomes in Newfoundland's rural sector. Forest industries have a well developed multiplier effect. Studies of forest based communities have indicated that one basic forest industry job is associated with two additional non-basic jobs in the supply and service industries.[56]

  Although the employment impact of energy plantations is expected to be less than the forest based industries as the inter-industry linkages would not be as great, the impact on rural communities would still be significant. Swedish studies indicate that two people would be employed per 100 hectares of energy plantation.[57] Furthermore, employment would be fairly stable as demand for biomass from energy plantations would normally be independent of the abrupt market cycles experienced by traditional forest industries dependent upon international markets.

- The majority of skills utilized in energy plantations are present in many rural communities in Newfoundland due to traditional economic ties to forestry, forest

industries and, to a more limited extent, agriculture. Consequently, the majority of operations could be undertaken by the work force presently available in rural communities without requiring extensive training programs.

- Expenditures on local goods and services similar to those provided by the forest industry would flow from the development of energy plantations. Furthermore, revenues would accrue to various levels of governments through a variety of business, corporate and personal income taxes and to a lesser extent, the leasing of Crown forest land.

- The development of energy plantations could make effective use of large areas of marginal forest land that is presently underutilized. If the requirement for energy plantations was terminated, the land would be in an improved state which could be readily converted to other uses.

- The development of energy plantations could stimulate new research in forestry and biotechnology in Newfoundland. It is anticipated that spin-offs from this research could benefit other provincial forest resource programs.

- The demand for specialized equipment for energy plantations could present new opportunities for Canadian equipment manufacturers.

- The economics of energy plantations are presently improving and will continue to improve in the future through ongoing research especially in the areas of genetic improvement and specialized equipment design. As a result of genetic and cultural research, average yields in the U.S. energy plantation research program have increased from 9 metric tonnes dm/ha/a in 1978 to 13 metric tonnes in 1987 and are anticipated to reach 17-20 metric tonnes by 1996.[58] Consequently, the ability of biomass from energy plantations to compete with alternative fuels should increase over time.

As discussed above, the development of energy plantations could have a positive impact on the Newfoundland economy. Nevertheless, there is also a wide range of concerns which should be addressed when considering the future development and implementation of an energy plantation program. Many of the concerns are of a general nature while others are quite specific and pertain to the models, assumptions and economic analyses presented in this report.

- Energy plantations utilize a developing technology. At present, there are no large scale commercial plantations in the boreal forest regions dedicated to the production of energy feedstocks. Consequently, commercial cost estimates must rely on theoretical evaluations, findings from research trials, experience with pulpwood silviculture and analyses from the agricultural sector. Little experience is available to confidently base cost data upon as marked differences may occur between experimental and commercial scale operations. Major risks and uncertainties are still present and only experience gained from large scale commercial operations will clearly identify their impact.

- The analysis in this report is limited to an examination of the economics of generating steam from three feedstocks and is also based on a large number of assumptions. The generation of steam was selected as the most appropriate end-use for energy plantation biomass in Newfoundland at present. It is

important to note that the competitive position of energy plantation biomass could change substantially according to the conversion pathway selected as well as the scale of operation. It is recommended that the economics of other conversion technologies such as the generation of electric power from biomass as well as various scales of operation be examined in the future and compared with the findings from this study.

- Plantation cost estimates in this report are based on the operation of a wide range of specialized machinery of which many components are presently in the research and development phase. Several more years and substantial funding will be required to develop the full range of specialized equipment for the plantation operation. Furthermore, commercial development of the equipment will not likely proceed until a substantial market is perceived by equipment manufacturers. As the specialized equipment will tend to be expensive, the development of energy plantations in Newfoundland based on the utilization of this machinery must be on a fairly large scale to justify the equipment cost.

- Research programs directed to the development of energy plantations in the United States and Sweden envisage plantations being developed on underutilized agricultural land. Due to agricultural land constraints, the majority of energy plantations in Newfoundland would likely be established on marginal forest land. The site establishment costs and plantation yields in the hypothetical case study have been adjusted to allow for the lower quality sites in Newfoundland. However, it is possible that the specialized equipment currently being designed for plantations located on agricultural land may not cope with the stumps and stoniness found in forest land in Newfoundland. Additional problems may also be created by adverse winter weather conditions.

- Research findings have indicated that control of competing vegetation is critical to the success of establishing hardwood trees. In the U.S. program, research findings suggest that intensive weed control can double or triple growth rates and ensure acceptable survival rates and resistance to climatic extremes, diseases and pests.[59] The model utilized in this report includes an application of herbicide during the planting operation and mechanical weeding in the third year of each rotation. Field operating experience may indicate that more intensive weeding is required prior to canopy closure. Tending costs would have to be increased to reflect a more intensive operation.

- In general, the detrimental effects of nutrient drain have not been significant under long term cutting cycles associated with commercial timber harvesting. However, whole tree harvesting under short rotations could affect the nutrient balance even when tree foliage is not harvested. Elemental losses sustained over several cycles may not be renewed by atmospheric inputs, mineral weathering or natural fixation.

  The literature on this subject reveals a lack of consensus. As discussed previously, the NRCC analysis of five year rotation plantations used as a base for this report determined that the reduction in the cost per tonne of biomass resulting from increased yields through the application of fertilizer were not significant. Consequently, the application of fertilizer was not included in the hypothetical plantation for Newfoundland. In the U.S. research program, it is

generally accepted that the plantations will require nutrient admendments either to maximize growth or to prevent degradation of the sites.[60] Experimental trials in Newfoundland suggest that fertilization will be necessary to maintain yields over successive rotations.[61] Consequently, if foliar or soil analyses in future energy plantations in Newfoundland show deficiencies of nutrients over time, fertilizer will have to be applied to maintain or increase yields. No allowance has been made in the Newfoundland plantation cost estimates to account for this possibility.

- Large densely planted even-aged monoclonal stands of trees are very vulnerable to insects, mites, fungi, viruses and bacteria. Additional problems stem from damage caused by wildlife. Many of these problems are pervasive and difficult to control. On experimental plots in Newfoundland, stands have been damaged by moose browsing, stem cankers and crows removing cuttings. The impact of these risk related factors as well as the possibility of crop failure and possible delays in program implementation are very difficult to assess. In the future, the impact of these factors will likely be reduced somewhat as the large diversity of willows assists in the selection and breeding of clones that are resistant to disease, climatic extremes and other plant stresses. Furthermore, factors such as animal browsing can be controlled by fencing although this method of control may not prove to be cost effective.

- Little attention has been paid in energy plantation literature to inventory requirements. Harvesting of energy plantations in Newfoundland would normally be limited to approximately 120 days during the winter season when the trees are dormant. Due to space limitations at most energy conversion sites, it is assumed that the biomass would be stored at roadside on the plantation site until required. If the demand for biomass is constant throughout the year, the average monthly inventory would be four times the monthly demand. The cost of carrying this level of inventory could significantly increase the working capital requirements of an operation. One method of reducing the high inventory levels in Newfoundland would center on the harvesting and utilization of biomass from non-commercial natural forests during the summer months which would reduce the inventory requirements for energy plantation biomass.

The storage of biomass can also create problems. If the biomass is chipped immediately after harvesting and stored while moist, significant energy losses may occur. Research in Sweden on the drying and storage of forest industry logging residues has revealed that the energy loss varies between 7 and 21 percent during 6 to 9 months of pile storage if the residues are chipped.[62] Furthermore, microfungi are formed during chip storage which can cause allergic reactions.[63] The reactions are presumably caused by airborne fungal particles (spores and hyphae) which are inhaled when working with infected chips.

According to research findings, when branches and tops are stored intact in piles for 6 to 9 months, no significant energy losses occur.[64] To mimimize storage problems, it was assumed that biomass from energy plantations in Newfoundland would be stored at the plantation site in roundwood form and chipped immediately before transport. The plantation site would be used as a drying site to take advantage of direct solar energy and natural airflow as well as minimizing inventory space at the conversion plant site.

Additional storage problems may occur in the winter months with the handling and chipping of entangled snow and ice covered biomass. The storage of large quantities of biomass at roadside could also raise aesthetic concerns.

- A report prepared by the Meridian Corporation on SRIC culture of woody crops for energy states that little research has been undertaken on the environmental effects of SRIC energy plantations.[65] Recommendations leading to acceptable environmental practices must be based on experience gained in traditional forestry and agricultural practices as there is little information available on the long term effects of large scale energy plantations. Potential detrimental environmental effects which have caused concern include soil erosion, soil nutrient depletion, groundwater changes, leaching of fertilizers and other chemicals and wildlife habitat alteration. Despite these concerns, current research and development work in Sweden has not identified any environmental consequences that would constitute an obstacle to the introduction of energy plantations in Sweden.[66]

- The basic suitability of wood as a feedstock has also been challenged. Arguments against the use of wood as a fuel have generally centered on its relatively low bulk density causing inefficiencies in transport, high moisture content and low energy content on both a weight and volume basis.

- The issue of competing land use must also be addressed as commercial scale energy plantations with modest yields require a large land area. Care must be taken that the land used for energy plantations will earn at least as much as its opportunity cost. As energy plantations in Newfoundland will likely be established on marginal forest land, competing uses for the land will not likely pose a problem as alternative land uses such as pulpwood production would normally be established on higher quality land.

- Prior to the implementation of commercial energy plantations in Newfoundland, consideration must be given to the increased utilization of large volumes of biomass in non-commercial natural forest stands consisting of insect damaged, fire damaged, scrub, hardwood and residual cutover stands. Utilization of the biomass would reduce the cost of rehabilitating productive forest land currently supporting nonmerchantable stands. During the 1980's, the Newfoundland Department of Forest Resources and Lands and the Department of Mines and Energy jointly promoted the development of a commercial wood chip industry based on the utilization of these stands.

A recent study identified 5.45 million tonnes of economically accessible wood fuel located within a 80 kilometer radius of Gander, Grand Falls, Corner Brook and Stephenville.[67] The majority of wood fuel identified in the study was located in standing forests. Estimates by the Department of Forest Resources and Lands indicate that demand for fuelwood chips in the four regions could total 197 thousand green tonnes annually.[68] In comparison, only 29 thousand tonnes of fuelwood were obtained from in-forest chipping operations in Newfoundland in 1986.[69]

In addition to the large reserves of fuelwood in existing stands, approximately 11 percent of the area of the province is peatland with large deposits located near potential demand centers.[70] The economics of utilizing peat as an energy

feedstock are currently under review.[71] Furthermore, the impact of offshore petroleum and gas developments must also be taken into consideration as these developments could influence the competitive position of wood fuels.

- The viability of energy plantations in Newfoundland will be directly influenced by the price of fossil fuels. Current price outlooks for fossil fuels show much smaller increases in real prices than earlier forecasts. Large increases in international oil prices, which would enhance the attractiveness of energy plantations, are not anticipated in the future.

Future world oil prices will depend on the international supply and demand for oil as well as the influence OPEC can exercise on price levels. Due to uncertainties in the international oil market, the National Energy Board developed two price scenarios for oil in a recent publication forecasting Canadian energy supply and demand to the year 2005.[72] In the low price scenario, real crude oil prices were forecast to increase to U.S $18 per barrel (1986$) by 1992 and remain unchanged in real terms to the year 2005. In the high price case, crude oil prices were forecast to increase to U.S. $27 per barrel by 1993 and remain constant over the projection period. The ceiling of U.S. $27 per barrel was considered to be the price at which energy producers other than OPEC could enter the market and constrain the ability of OPEC to sustain prices above the ceiling. According to the NEB, the majority of recent price forecasts prepared by governments and the private sector fall within the range set by the two scenarios.

The impact of the crude oil price forecasts on average Canadian retail prices in the Atlantic Region are shown in Appendix 2 Table 1. Variations in world oil prices are dampened at the retail level as retail prices incorporate sales and excise taxes as well as transmission and distribution costs which tend to be relatively stable in real terms. In the year 2005, the low price scenario sets the real average retail price of heavy fuel oil for industrial users at $4.17 per GJ (1986$) compared to an actual price of $7.05 per GJ in 1985. In the high price scenario, the price of heavy fuel oil reaches $5.93 per GJ.

A major finding of the NEB report suggests that the use of alternative forms of energy such as wood, wind and solar power will increase in the future, however, their share of total energy use is unlikely to increase due to relatively low prices forecast for conventional energy forms. Consequently, on the basis of the NEB forecasts, it is unlikely that the economic viability of energy plantations will be substantially enhanced in the future by a major and sustained increase in the international price of oil.

8. CONCLUSIONS

The objective of this report is to assess the competitive position of fuelwood from proposed energy plantations in Newfoundland. Research on energy plantations in Newfoundland has been conducted by the Canadian Forestry Service since 1982. Furthermore, there is considerable experience and continuing interest in Newfoundland in the use of wood as an energy feedstock, particularly in the generation of steam for process and space heating requirements.

The assessment of the competitive position of biomass from proposed energy plantations is based on a "usable energy" approach taking into account the heat value and cost of each feedstock as well as the operating parameters and cost configurations of the system recovering energy from the feedstock. The three energy feedstocks examined in this report are biomass from hypothetical energy plantations, biomass from non-commercial forests in central Newfoundland and fuel oil. The conversion system is based on the generation of steam in wood and oil fired boilers.

The cost estimate of biomass from hypothetical plantations in central Newfoundland is $54 per ODT. This estimate is substantially higher than the estimate of $31.76 per ODT ($1985) developed by the NRCC for a similar operation in eastern Ontario. Site preparation, chipping, overhead and administration, and harvesting are the major cost elements in the Newfoundland operation. It is important to note that the specialized equipment upon which these cost estimates are based is not commercially available at present.

From the viewpoint of an industrial or commercial consumer of energy feedstocks, biomass from energy plantations will only be considered a viable energy source when the cost of energy from plantation biomass is equal or lower than the cost of alternative fuels. Based on the specific assumptions used in this report, the cost of steam generated from plantation biomass is $6.63 per GJ. This estimate is very similar to the cost of steam generated by biomass from natural forests in central Newfoundland and is significantly lower that the cost of steam generated from fuel oil. Consequently, the findings suggest that energy plantation biomass could compete with the two major feedstocks used in central Newfoundland for the generation of steam.

Many positive social and economic benefits could accrue from the development of energy plantations in Newfoundland. The plantations would assist in reducing Newfoundland's dependence upon imported oil, provide sustainable rural employment opportunities, increase government revenues, increase expenditures on local goods and services, effectively utilize marginal forest land and stimulate forestry research.

Energy plantations are based on a developing technology. At the current stage of development, no large scale commercial operations are present in the boreal forest regions to confidently base cost data upon and assess the risks and uncertainties associated with their establishment and operation. Consequently, the economic analysis in this report must be viewed with some degree of caution. Future commercialization of energy plantation operations in Newfoundland will be largely dependent upon the relative prices and availability of alternative fuels, the commercial availability of specialized plantation machinery, the reduction of biological and economic risks and

uncertainties through continuing research, and the level of interest generated in this concept by the government and private sectors.

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Appendix 1

ABBREVIATIONS

a	annum
C	centigrade
cm	centimetre
dbh	diameter breast high
dm	dry matter
ENFOR	Energy from the Forest Program of Research and Development - administered by the Canadian Forest Service
GJ	gigajoule
GJ/h	gigajoule per hour
ha	hectare
in	inch
kg	kilogram
kg/s	kilogram per second
kPa	kilo Pascal
kWh	kilowatt hour
m.c.	moisture content (wet basis)
MW	megawatt
NRCC	National Research Council of Canada
ODT	oven dry metric tonne (1,000 kg)
PMh	productive machine hours (75% of scheduled machine hours)
s	second
SEK	Swedish kroner
SRWC	Short Rotation Woody Crop
SRIC	Short Rotation Intensive Culture
TWh	terawatt hour
U.S.	United States
%	percent

Appendix 2

Table 1
Atlantic Region

Real Average Retail Price Forecast for Heavy Fuel Oil[1]
(1986 $/output gigajoule)

	Low Price Scenario		High Price Scenario	
	Commercial	Industrial	Commercial	Industrial
1985[2]	10.54	7.05	10.54	7.05
1990	5.96	4.05	7.72	5.21
1995	6.42	4.28	8.92	5.92
2000	6.32	4.13	8.78	5.84
2005	6.33	4.17	8.79	5.93

Notes:

1. Prices have been adjusted for burner tip efficiencies
2. Actual

Source: National Energy Board, Canadian Energy Supply and Demand 1985-2005, 1986.